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PERMEABILITY OF NICKEL TO HYDROGEN ISOTOPES

by

M. R. Louthan, Jr. and R. G. Derrick

Savannah River Laboratory
E. I. du Pont de Nemours and Company
Aiken, South Carolina

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DISCLAIMER

PERMEABILITY OF NICKEL TO HIGH PRESSURE HYDROGEN ISOTOPES*

M. R. Louthan, Jr. and R. G. Derrick

Savannah River Laboratory
E. I. du Pont de Nemours and Company
Aiken, SC 29801

The permeability, ϕ, of commercially pure nickel (Type 201; 99.5 wt % Ni + CO) to hydrogen isotopes at high pressures (up to 275 atm) was found to be in excellent agreement with the equation:

$$\phi = \frac{6.1 \times 10^{-2}}{5\sqrt{m}} \exp\left[-13{,}200/RT\right] \qquad (1)$$

where

m = mass number

ϕ = cc(gas) $s^{-1}cm^{-1}atm^{-1/2}$

This equation was previously developed from data for the permeation of hydrogen isotopes at low pressures (up to 4 atm) through high purity (∿99.999%) nickel.[1] Data presented in this note demonstrate that Equation 1 is also applicable to Type 201 nickel over a broad range of temperatures (297 to 652°K) and pressures (1 to 275 atm).

Several techniques were used to study the permeability of nickel to hydrogen. At low pressures (1 atm), steady-state permeation rates were measured for annealed foil specimens of about 3.8 x

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10^{-2} cm thick. Tests were conducted in an apparatus described previously.[2]

Protium permeation rates were determined from pressure rise measurements. Deuterium permeation rates were measured with a mass-4 leak detector. Tritium permeation rates were determined by collecting the permeating gas, expanding the collected gas into an ionization chamber, and measuring tritium decay with a vibrating reed electrometer. Permeation was measured at high pressures between 297 and 422°K and at low pressures between 359 and 652°K.

The permeability of Type 201 nickel to tritium is summarized in Figure 1. The effect of pressure on permeation was adjusted to one atmosphere by a Sieverts Law approximation. The Richardson-Arrhenius equation, determined by a least squares regression analysis of twenty-two individual measurements, is:

$$\phi_{T_2} = 1.1 \times 10^{-2} \exp[-12{,}900/RT] \qquad (2)$$

A similar analysis of the deuterium data, summarized in Figure 2, yields

$$\phi_{D_2} = 3.5 \times 10^{-2} \exp[-13{,}900/RT] \qquad (3)$$

The tritium and deuterium data were combined with low pressure protium permeation data by using the inverse-square-root-of-mass correction to approximate the isotope effect on permeability.[3] The combined data, summarized in Figure 3, are in excellent agreement with Equation 1 and also agree closely with the "best value" calculation of Robertson[4] for the permeability of nickel to protium at 1 atm or less and between 297 and 1333°K. The fit of the high pressure deuterium and tritium data to Equation 1 indicates:

- the inverse square root of mass correction predicts isotopic effects on hydrogen permeation through nickel over a wide range of temperature and pressure.

- a Sieverts Law approximation will predict the effect of pressure on hydrogen solubility in nickel up to 275 atm.

- the diffusivity of hydrogen in nickel is not concentration dependent.

This last conclusion is based on the observation that the maximum concentration of hydrogen in the high pressure test specimens is over 100 times the maximum concentration in the low pressure specimens. If diffusivity depended on concentration, the high and low pressure permeation data shown on Figures 1, 2, and 3 should not agree.

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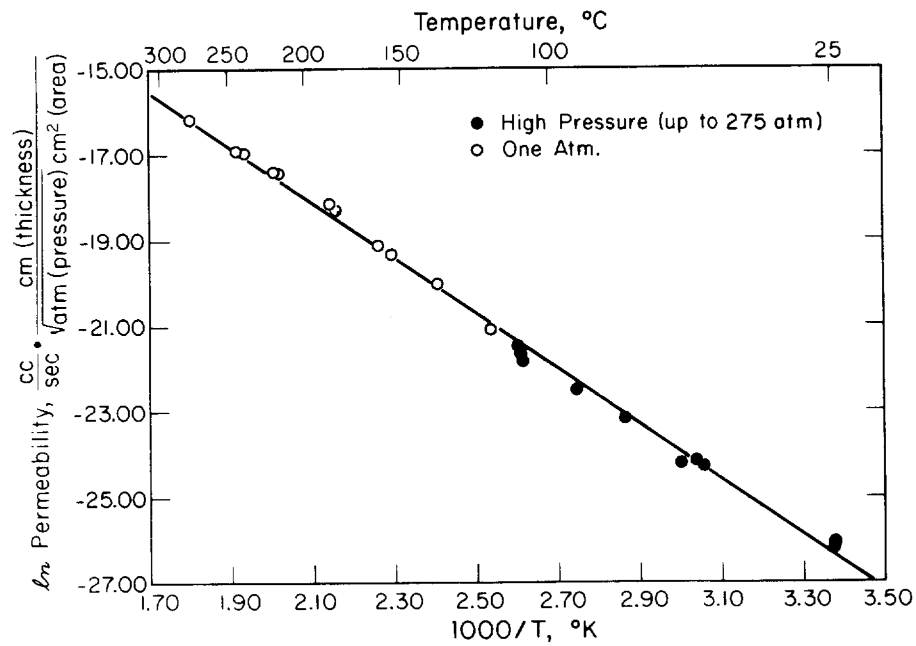

FIG. 1 PERMEABILITY OF TYPE 201 NICKEL TO TRITIUM

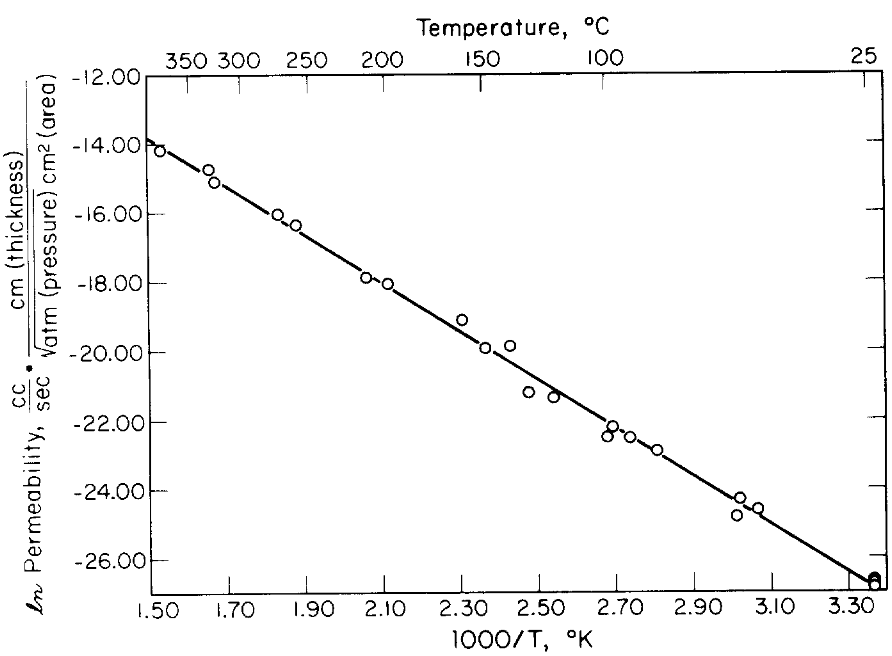

FIG. 2 PERMEABILITY OF TYPE 201 NICKEL TO DEUTERIUM
Pressures ranged from 1 to 275 atm.

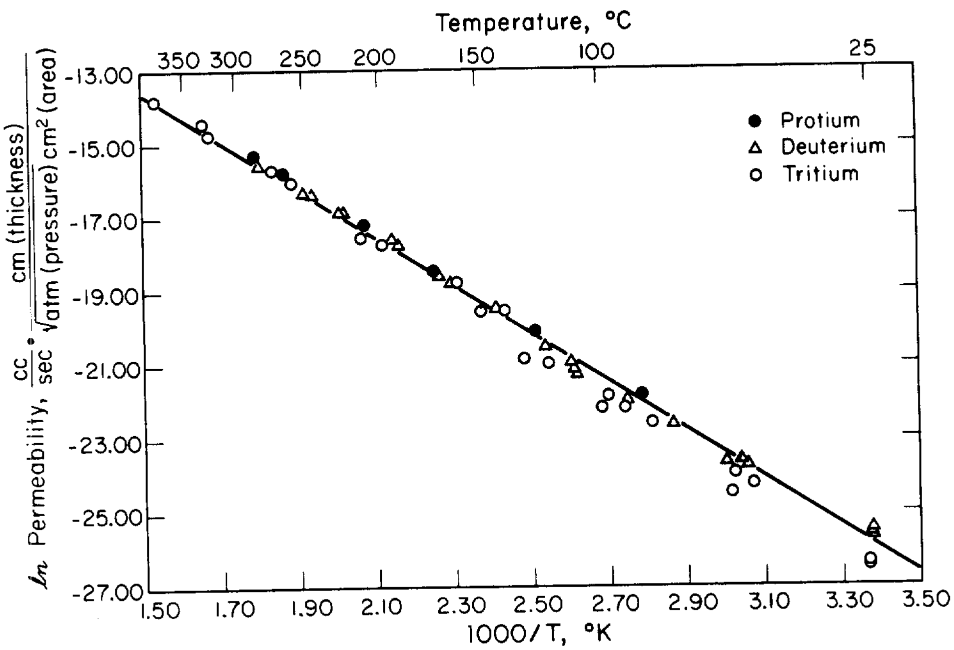

FIG. 3 PERMEABILITY OF TYPE 201 NICKEL TO HYDROGEN ISOTOPES
All data were normalized by the inverse-square-root-of-mass correction for isotope effect to mass of one and by Sieverts Law for pressure to one atm. Curve is calculated from Equation 1 for high-purity nickel.